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The annual and geographical distribution of cold pools

by
E.J. Sumner (Meteorological Office)

A previous study has been made (M.R.P. 764) of the more intense cold pools of the Atlantic-European sector of the Northern Hemisphere, for the 5-year period September, 1946 to August, 1951, inclusive. The present report deals with all the cold pools (areas within one or more closed lines in the 1000-500 mb. thickness topography and occurring on an 0300 G.M.T. chart) within the same region and for an almost identical period, viz., October, 1946 to September, 1951, inclusive. The precise area considered was bordered to the west by the 60°W meridian and to the east by the 30°E meridian. Pools north of 80°N and south of 30°N were omitted because the observational coverage was inadequate to locate all the pools which might have occurred there. It was however impossible to adhere rigidly to these boundaries for all purposes since some of the pools traversed them at some time during their existence, and in order to obtain accurate statistics of their duration for example it was necessary to follow them until they finally disappeared from the charts.

Thus in this report the following convention was adopted. Those statistics relating to the duration of pools (sections 1 and 2) apply only to those which passed at least a half of their total existence within the area in question, part of their lives (the lesser half) being spent outside in a minority of cases. Those statistics of more "local" significance, relating to cold pools en masse (sections 3 and 4), apply to all the pools within the area and to none other.

Another distinction observed here (in sections 1, 2 and 4) is between those pools which at some time during their existence reached intensity two or more* and those which were at the minimum intensity throughout.

1. The more intense pools. In M.R.P. 764 only those pools contained within two or more closed thickness lines and appearing on at least two successive 0300 G.M.T. circumpolar thickness charts, were considered. These 75 pools were often extended before and/or after by periods during which they were weaker, i.e. of intensity one, and were on occasions followed outside the specified area. The above requirement that the pools must spend not less than half their total life within the area, reduces their number considered herein to 54. To these may be added 9 cases associated with them (or with larger pools outside the area) as subsidiary features, i.e., contained within a common outer closed thickness line but lasting only a day, and 111 which appeared on only one 0300 G.M.T. chart at intensity two or more. The latter however usually lasted beyond a day as weaker pools.

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* The intensity of a cold pool is defined in accordance with the convention: one closed thickness line, intensity one; two closed lines, intensity two; ..... and so on. The isopleths are drawn at intervals of 200 ft. (even hundreds) on the circumpolar charts.

The frequency distribution of the duration of these 174 more intense pools (viz., those which at some time or other were of intensity two or more) is shown in Fig. 1. For each spell duration, the number of pools of the minimum intensity is indicated together with the 'internal' distribution of periods (usually continuous) at the higher intensities (two or more). The average duration of these pools is 4.0 days with a mode of 3-4 days. One-day pools are very infrequent, so that a forecaster can be fairly certain that an intense pool will still be present 24 hours after its first appearance.

2. The weaker pools. The remaining pools are necessarily of intensity one throughout; their frequency distribution is shown in Fig. 2. These weaker pools were usually quite ephemeral, most frequently lasting only a day, the average duration being 1.6 days.

3. Central thickness anomalies. A measurement of the 1000-500 mb. thickness at the centre of each pool was made, by interpolation to the nearest 50 ft. The frequency distribution of central thickness anomaly (departure from a 5-year mean for the appropriate month) is shown in Fig. 3, the pools now being segregated simply in accordance with their intensity. The more intense pools (intensity two or more) always had a central thickness below the average for the time and place, their average anomaly being -570 ft. The intensity-one pools, too, almost invariably had a central thickness below average but with a higher general level of thickness, the average anomaly being -345 ft.

4. Annual and geographical distribution. The distribution by months throughout the year of the more intense and the weaker pools is shown in Figs. 4 and 5, respectively, each occurrence on an 0300 chart now being counted. These are largely the pools considered in sections 1 and 2, but the totals are not the same because of the convention described in the introduction, which now excludes the pools which passed outside the area.

The occurrences of the more intense pools were most frequent in May and June and least frequent in August and again in January, as previously demonstrated in M.R.P. 764 for somewhat similar data. The weaker pools, on the other hand, have a very dissimilar distribution, with a pronounced maximum in August.

There were often several pools simultaneously present on an 0300 G.M.T. chart: on about 55% of occasions there was only a single pool, with two pools per chart on about 30% and three pools on 12%; the remaining 3% had four and (rarely) five pools per chart. There were less pools per chart in winter than summer, the respective figures for charts with a single pool being about 70% and 40%.

The monthly mean thickness anomalies for each of the above classes are shown in Table I.

Table I. Monthly mean thickness anomalies: tens of feet

Pool within type of spell	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
More intense	62.5	47.6	54.1	50.8	40.6	40.1	39.3	37.2	41.3	42.1	35.1	60.0	42.6
Weaker	31.3	36.1	33.5	34.9	29.2	34.1	30.9	27.2	29.6	30.4	34.0	31.3	31.3

For the pools of the weaker spells there is little change in the mean anomaly from month to month, whereas for the more intense pools there is a distinct seasonal variation.

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The positions of all the pools (occurrences at 0300 hours) within the area have been plotted on charts, a month at a time (Figs. 6-17). Pools of intensity two or more are distinguished from lesser pools. The main features of their geographical distribution are as follows:-

(1) From October to March the pools are mainly concentrated over Europe and in the Mediterranean. Within this period, there are also several regions with either no pools at all in some months or a very sparse coverage in others. The most noticeable of these are: the area from Greenland eastwards to the Norwegian Sea in latitudes 60-70°N, and the region of the Atlantic in about 40-50°N extending eastwards from the American seaboard to as far as 10°W in January but less in other months.

(2) From April to September cold pools are more uniformly distributed over the area considered, although still thinnest in the regions mentioned in the previous paragraph. Also they become very infrequent in the Mediterranean in July and August.

(3) There is a marked scarcity throughout the year in the extreme south-western corner of the area. This may however be partly due to the small number of upper-air observations there.

(4) Areas subject to cold pools usually have both classes of intensity. One exception is, however, the area roughly west and north-west of the British Isles (extending to 30-40°W some months) where the more intense pools are practically non-existent, or if they do occur quickly weaken. A synopsis of all the data, on a seasonal basis, is contained in Fig. 18.

5. Comments. As has been remarked by C.K.M. Douglas (1947), cold pools are most frequent when and where the normal latitudinal temperature gradient is weak. The annual distribution of the weaker pools (Fig. 5) is certainly in keeping with this principle. Moreover, an inspection of the monthly mean thickness charts for the corresponding 5-year period, revealed that for all the pools the greatest areal concentrations each month also occurred where the mean thermal gradients were weak. The converse is not, however, always true; for example, the winter minimum of pools over Iceland is in an area for which the thermal gradient is as weak as over Europe, where the maximum concentration occurred. The (inverse) relationship between the mean thermal gradient and the number of cold pools is not of course a direct causative one: the reverse effect, viz., the more pools that occur the weaker the mean thermal gradient becomes, must operate to a large extent.

Although the maximum monthly concentrations of the pools occurred in association with weak troughs in the monthly mean thickness topography, there were (lesser) concentrations associated with weak ridges, e.g., that over and to the west of the British Isles in February.

The seasonal distribution of the more intense cold pools is rather difficult to explain. One might possibly expect a late spring and a late autumn optimum on the grounds that the mean thermal gradient is too strong in winter and the heating too intense in summer, to allow the formation of large pockets of relatively cold air in the Atlantic and European sectors. The mean figures in Table I suggest how much colder the air has to be in winter in order to establish an intense cold pool against the strong prevailing thermal gradients. In summer, on the other hand, a much smaller anomaly would suffice to give an intensity-two pool but this is evidently seldom achieved in face of the (non-adiabatic) warming.

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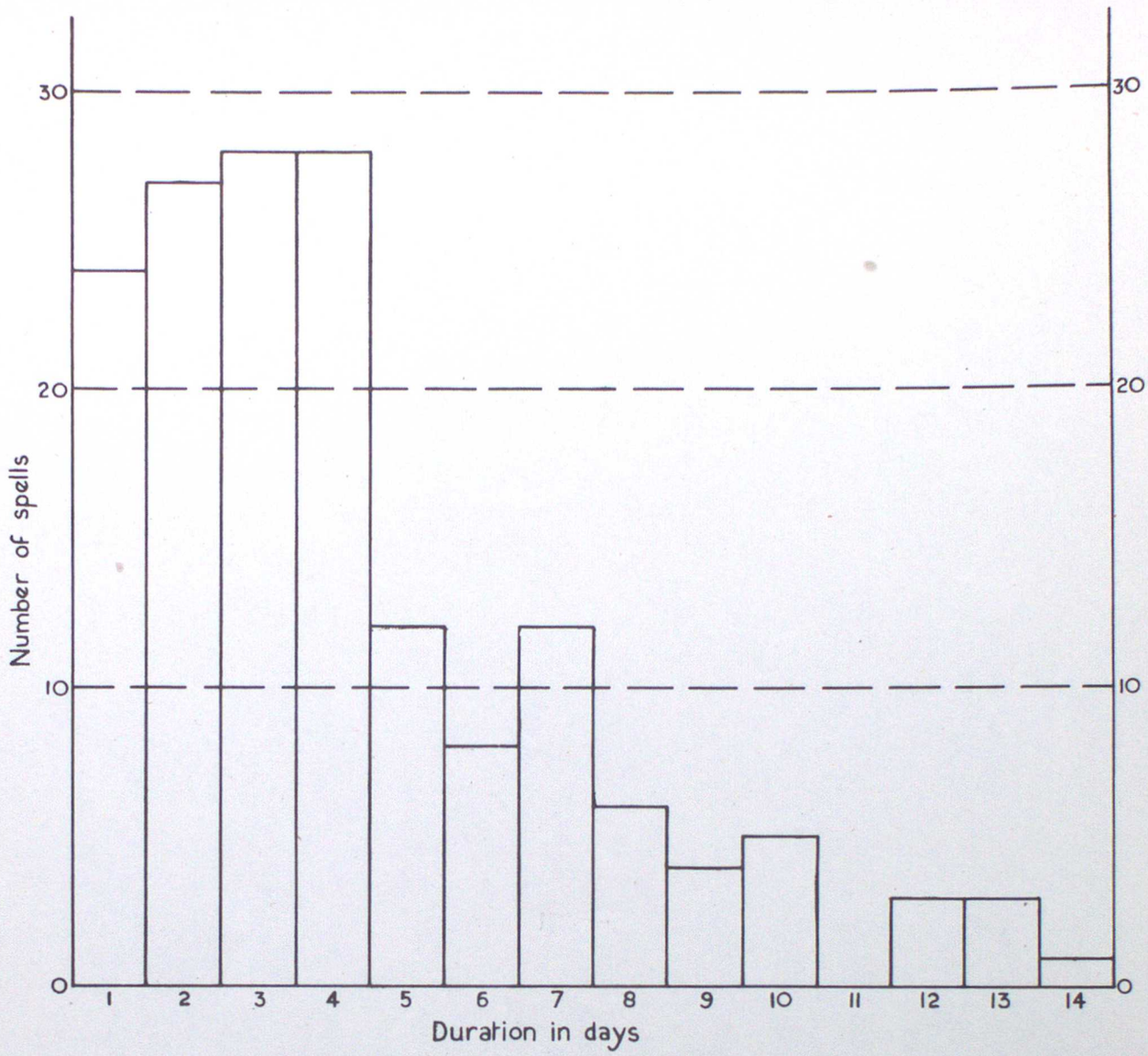
The enhanced late spring and early summer peak, and the relative "failure" of the late autumn maximum, must be connected with the seasonal warming and cooling, respectively, and with the synoptic systems which are associated with these processes. The association of the more intense cold pools with blocking, which has a similar seasonal distribution in the same sector (see Bretzowsky et alia, 1951, for example), is probably significant in this connection.

References

Bretzowsky, H., H. Flohn and P. Hess - Some remarks on the climatology of blocking action. Tellus, Vol. 3, No. 3, 1951.

Douglas, C.K.M. - Cold pools. Met. Mag., Vol. 76, No. 903, 1947.



The figures given below represent the number of occasions on which pools of a given spell duration (reading across) were of intensity two or more for (reading down) one day, two days ---etc., respectively (usually but not necessarily consecutively)

No. of days at intensity two or more	Length of spell in days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	24	25	24	13	5	1	4	2	1	1	—	—	—	—
2		2	4	11	6	4	5	2	—	1	—	1	1	—
3			—	4	1	—	1	—	1	1	—	—	1	—
4				—	—	1	1	1	1	2	—	1	1	—
5					—	1	1	—	1	—	—	1	—	—
6						1	—	—	—	—	—	—	—	—
7							—	1	—	—	—	—	—	—
8								—	—	—	—	—	—	—
9									—	—	—	—	—	1

Occurrences of pools on 0300 Z charts

Total no. of pools of higher intensity (≥2)	24	29	32	47	20	24	26	17	13	14	—	11	9	9
Total no. of intensity one	0	25	52	65	40	24	58	31	23	36	—	25	30	5

Fig.1 The more intense cold pools: Frequency distribution of spell-duration October 1946 – September 1951

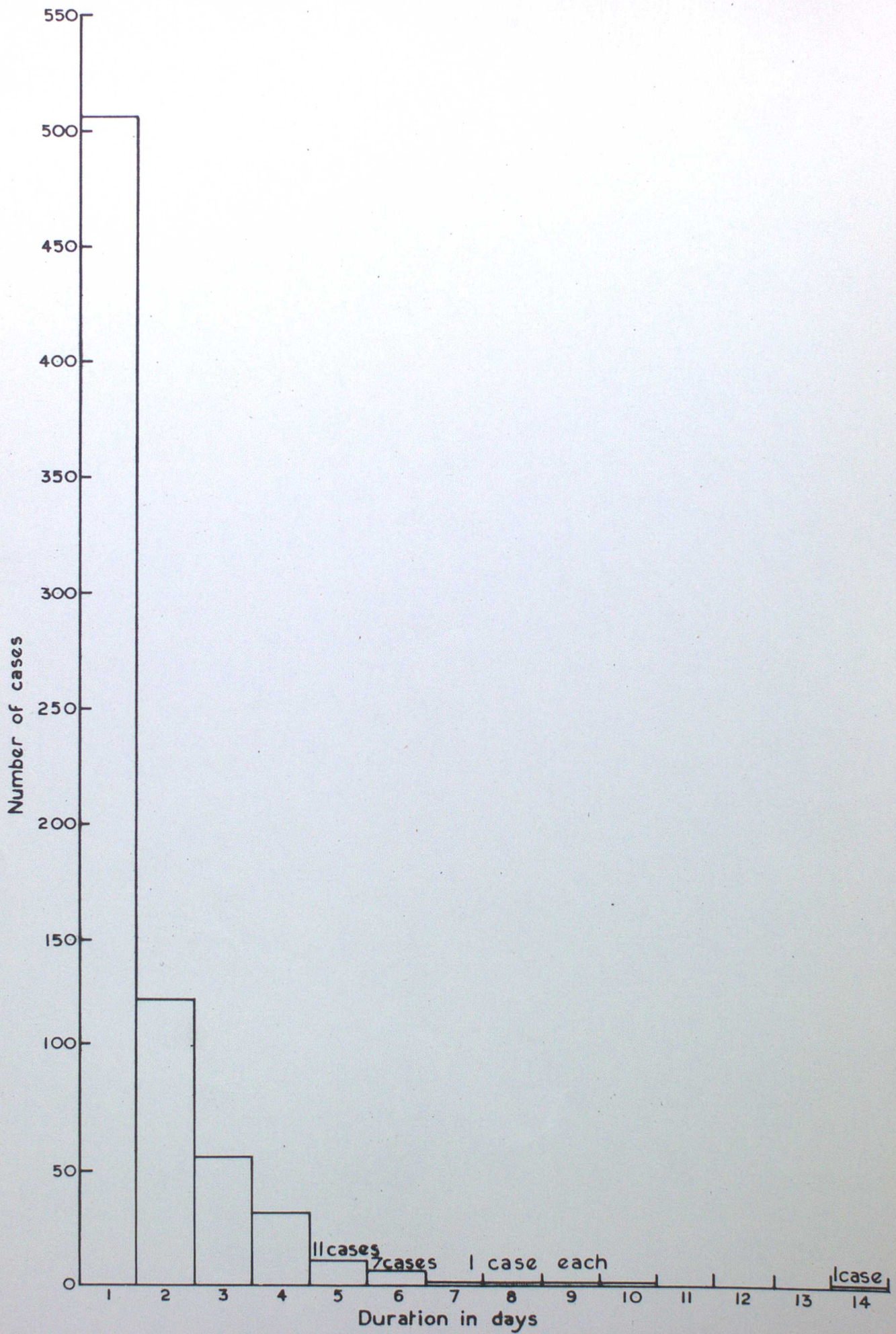
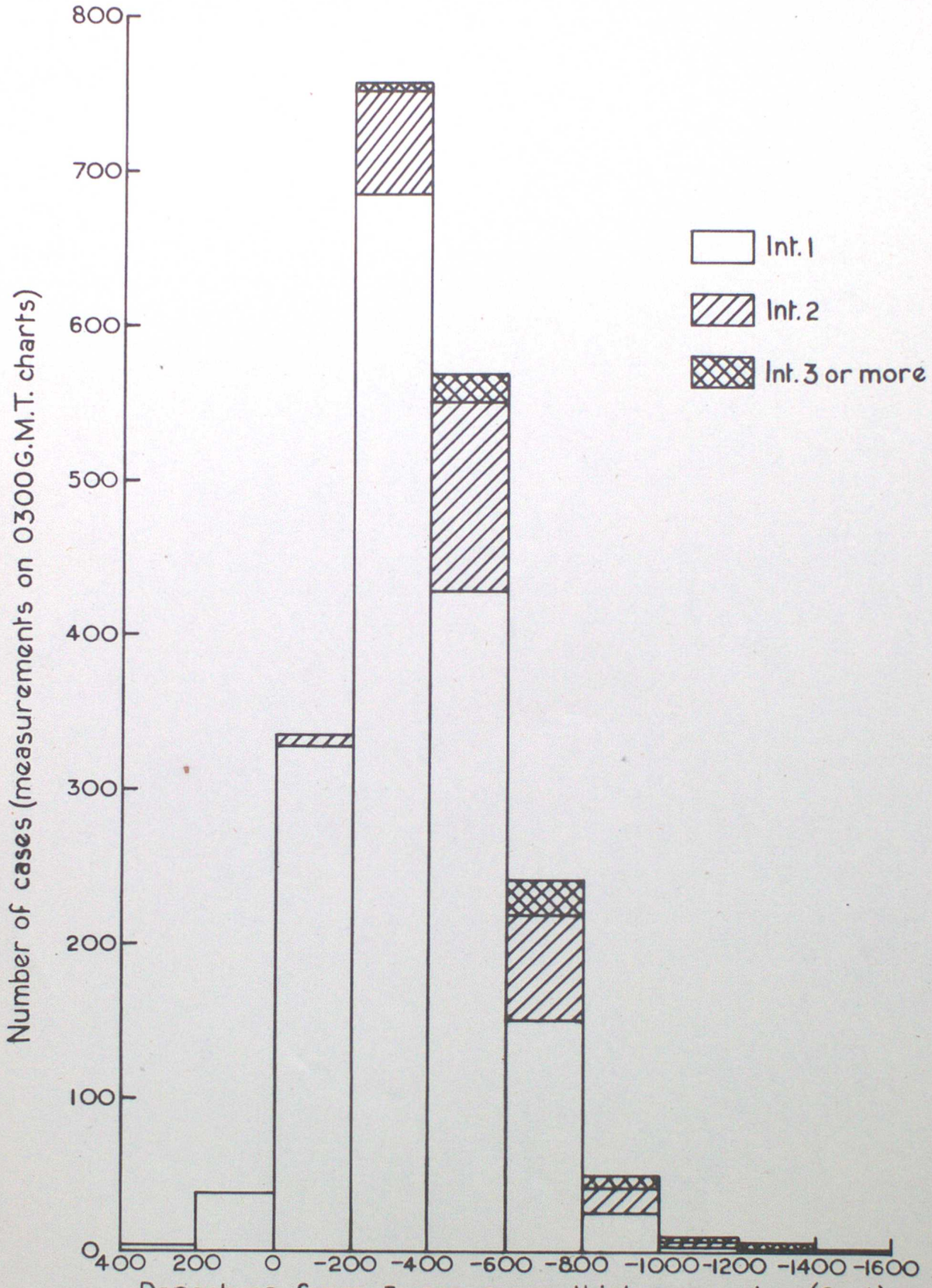


Fig. 2 The weaker cold pools: Frequency distribution of spell duration October 1946 – September 1951



	Number of cases										Total
Int. 1	3	38	327	684	429	150	26	3			1660
Int. 2			7	68	123	68	26	3	1		296
Int. 3				4	16	23	7	3	4	1	58

Fig. 3 Frequency distribution of thickness anomalies of all cold pools entirely within area specified

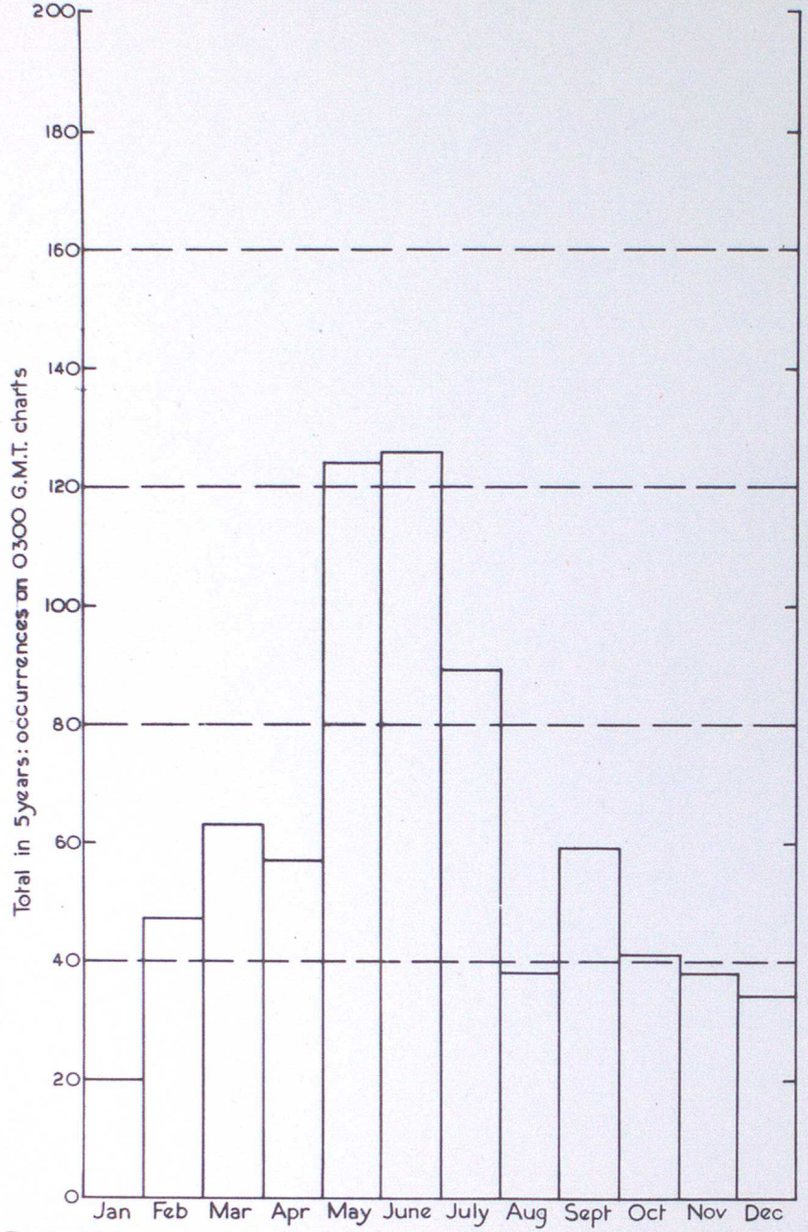


Fig.4 Histogram of monthly distribution of the more intense pools
(Each occurrence on an 0300z chart counted once)

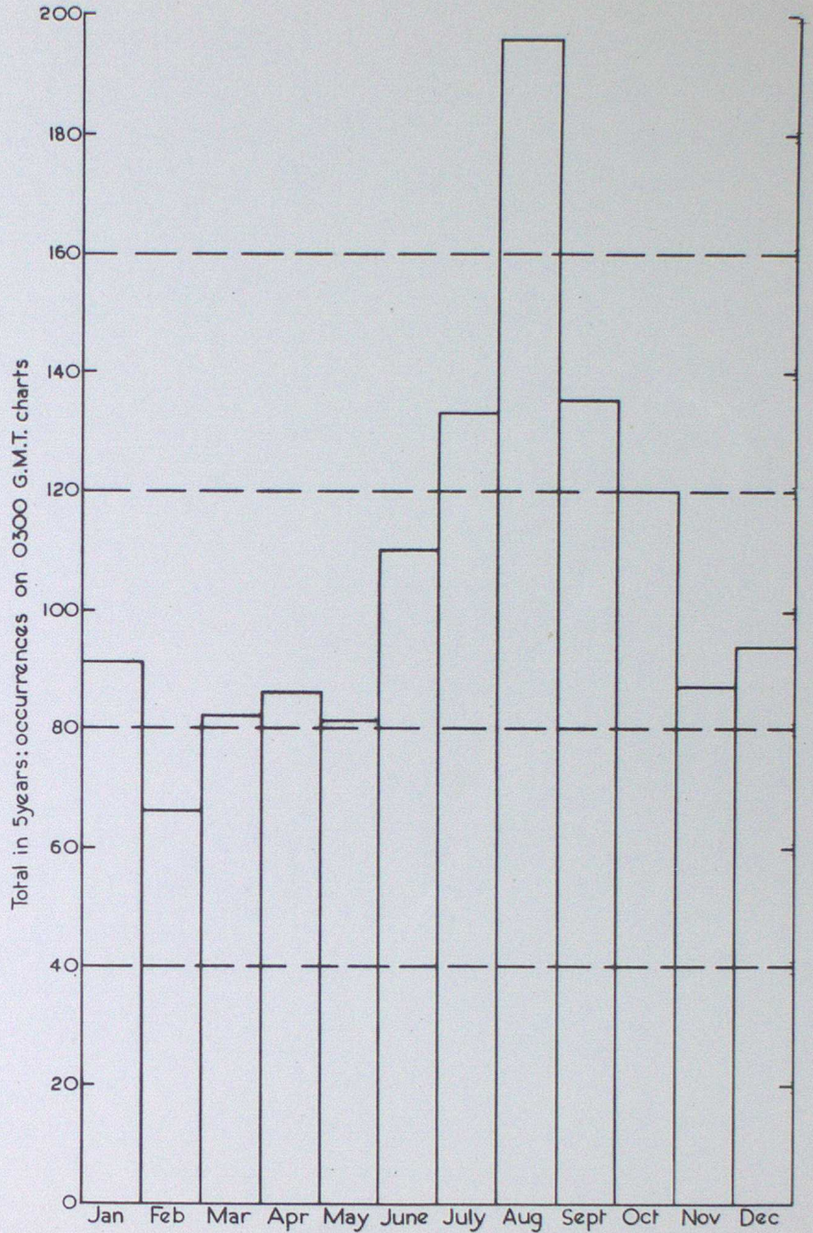


Fig.5 Histogram of monthly distribution of the weaker pools

Cold Pools: October 1946 – September 1951

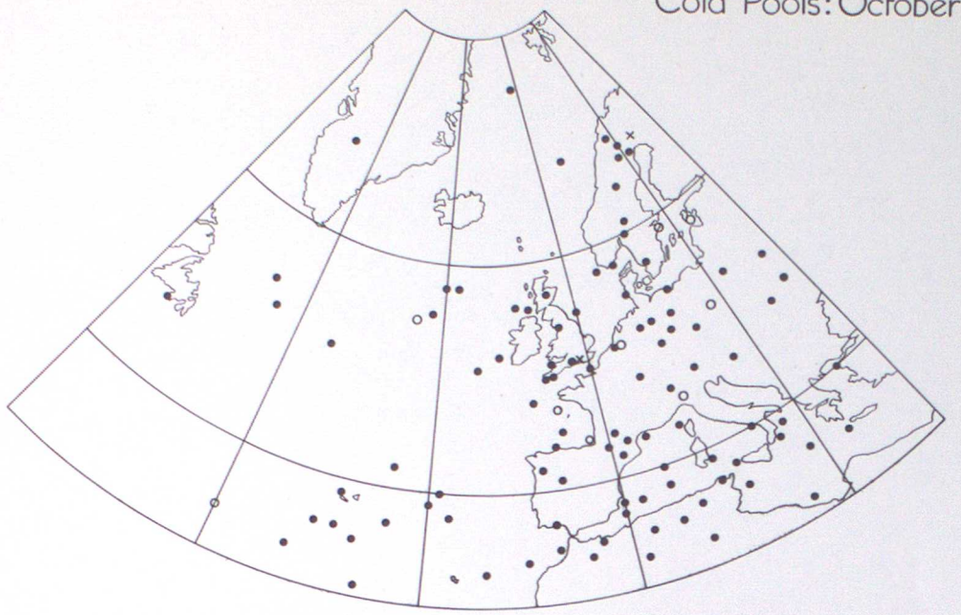


Fig.6 January

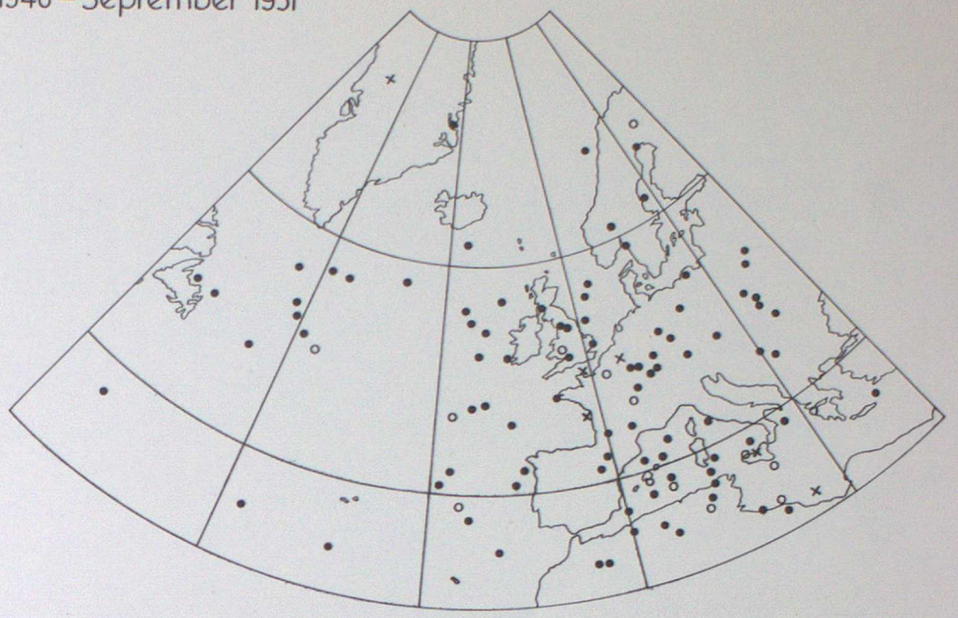


Fig. 7 February

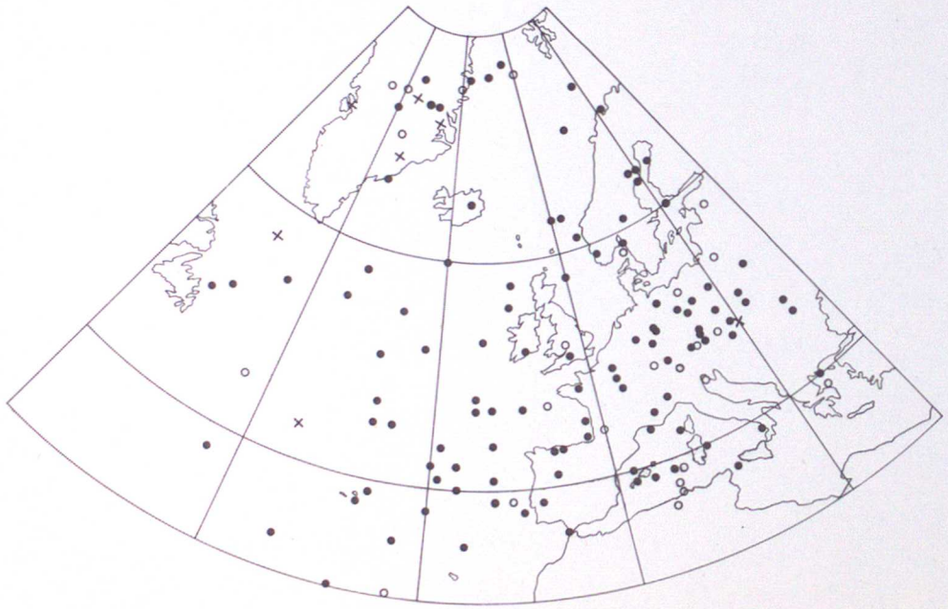


Fig.8 March

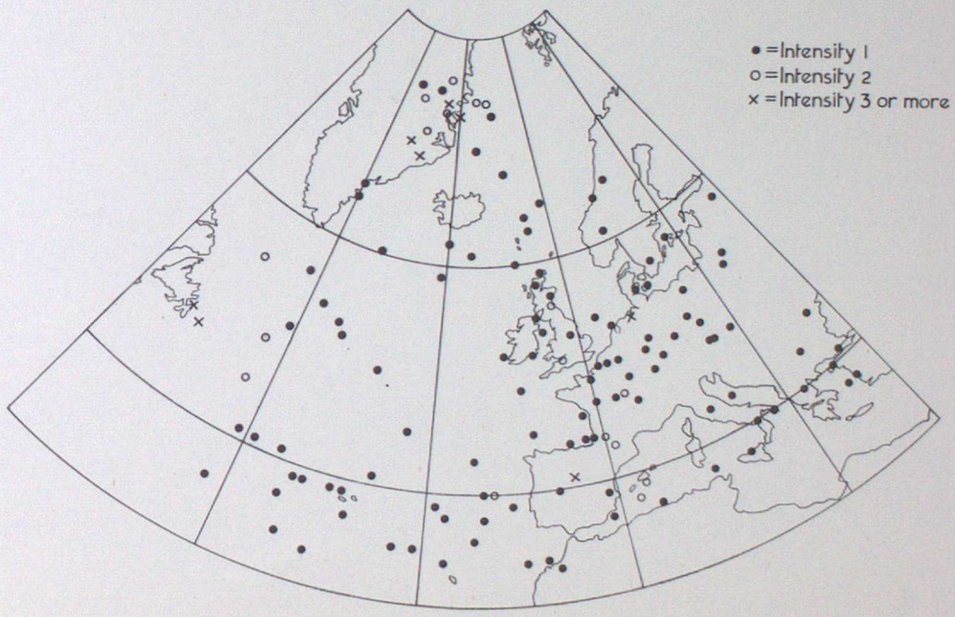


Fig. 9 April

Cold Pools: October 1946–September 1951

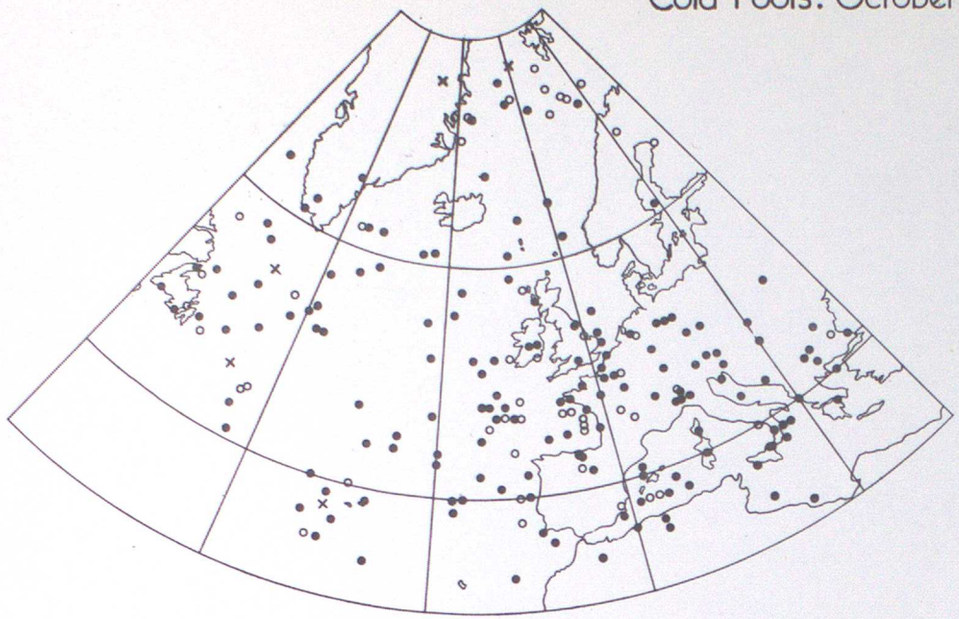


Fig. 10 May

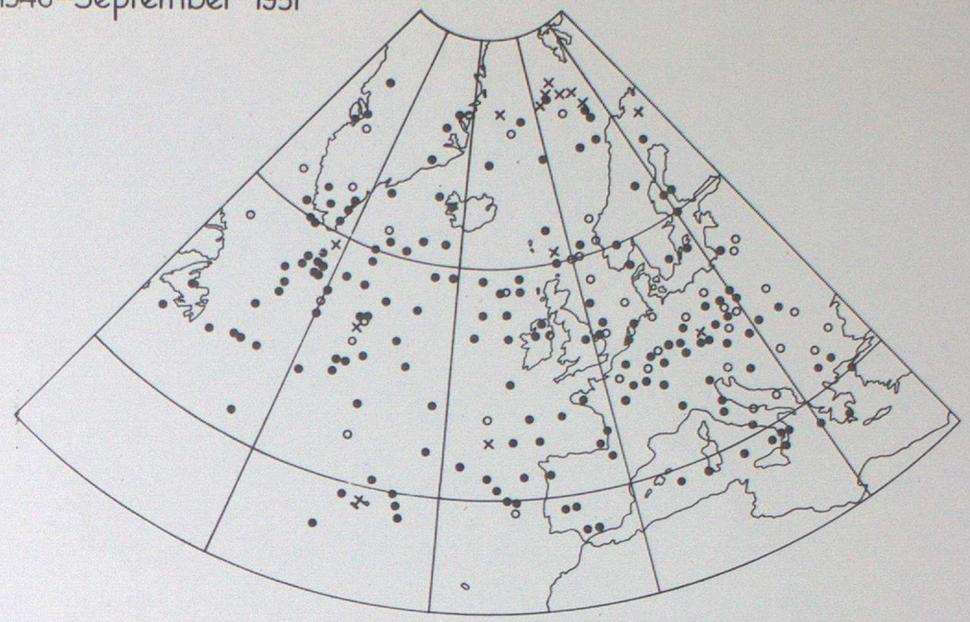


Fig. 11 June

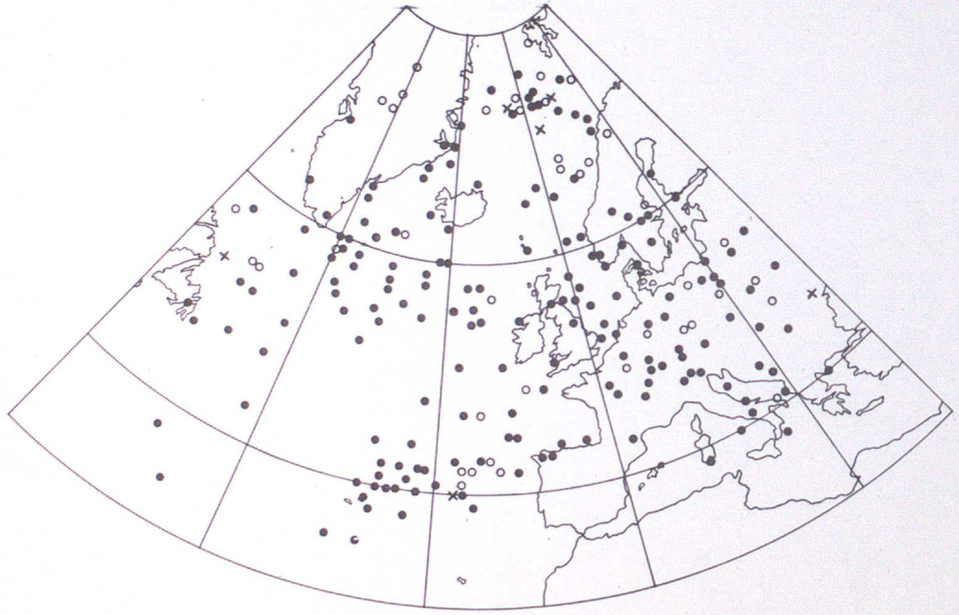


Fig. 12 July

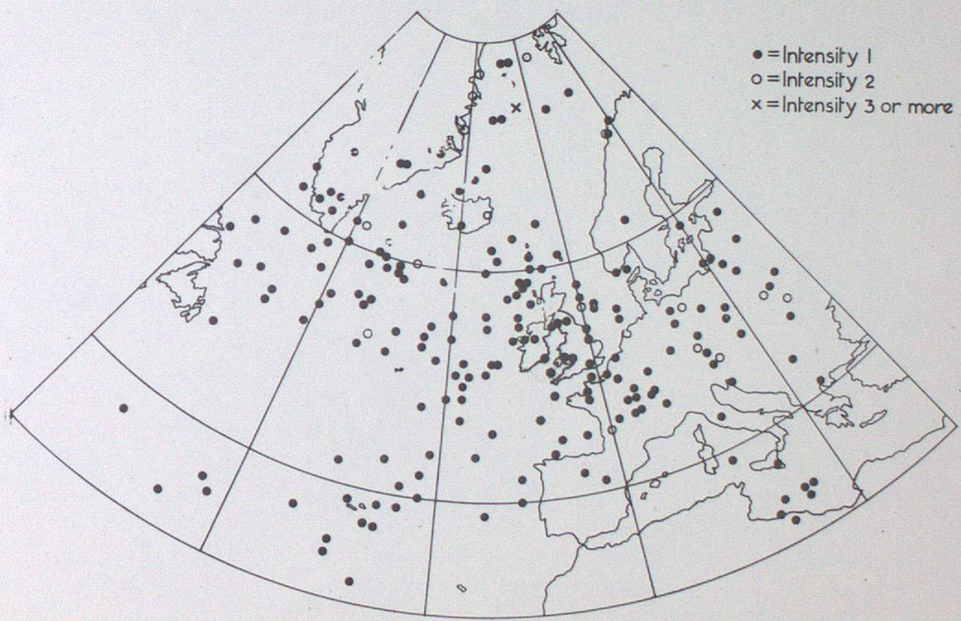


Fig. 13 August

Cold Pools: October 1946–September 1951

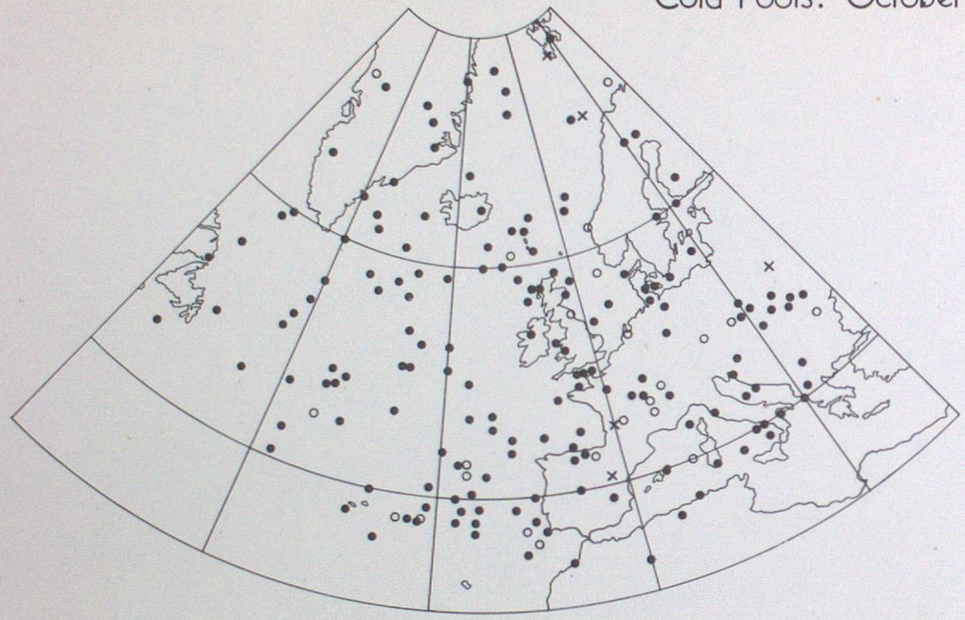


Fig.14 September

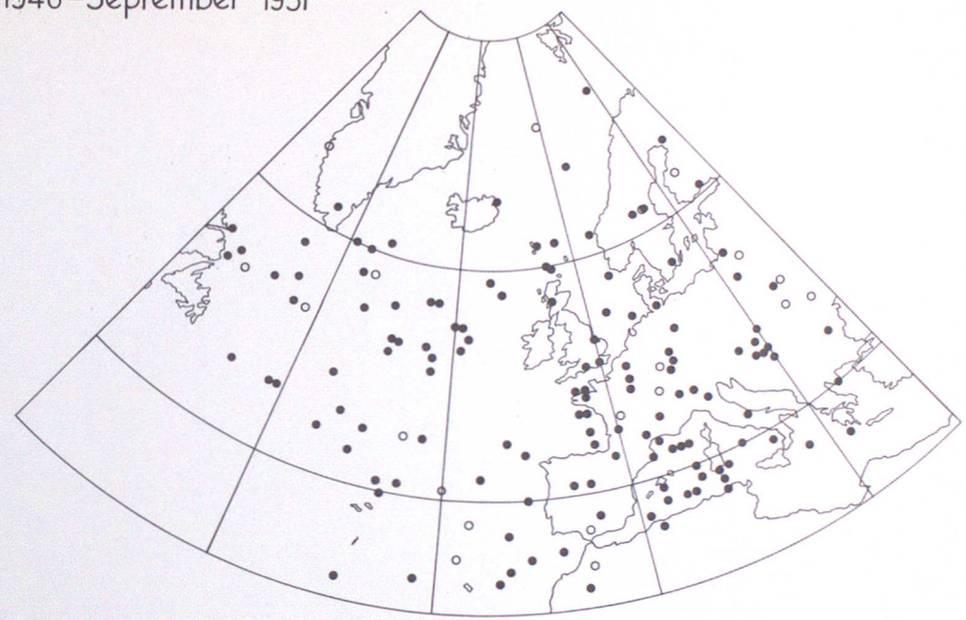


Fig.15 October

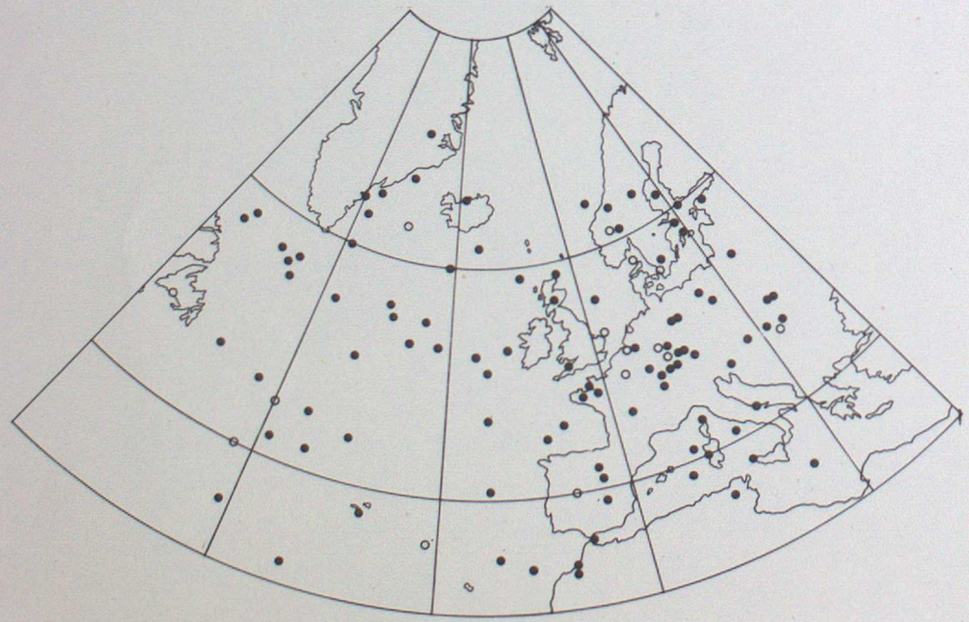


Fig.16 November

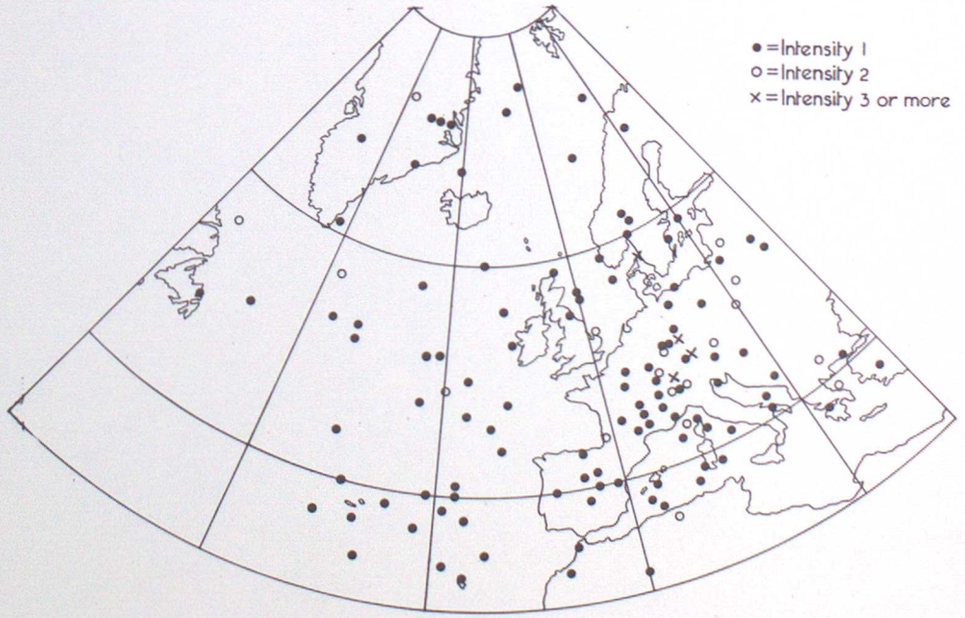


Fig.17 December

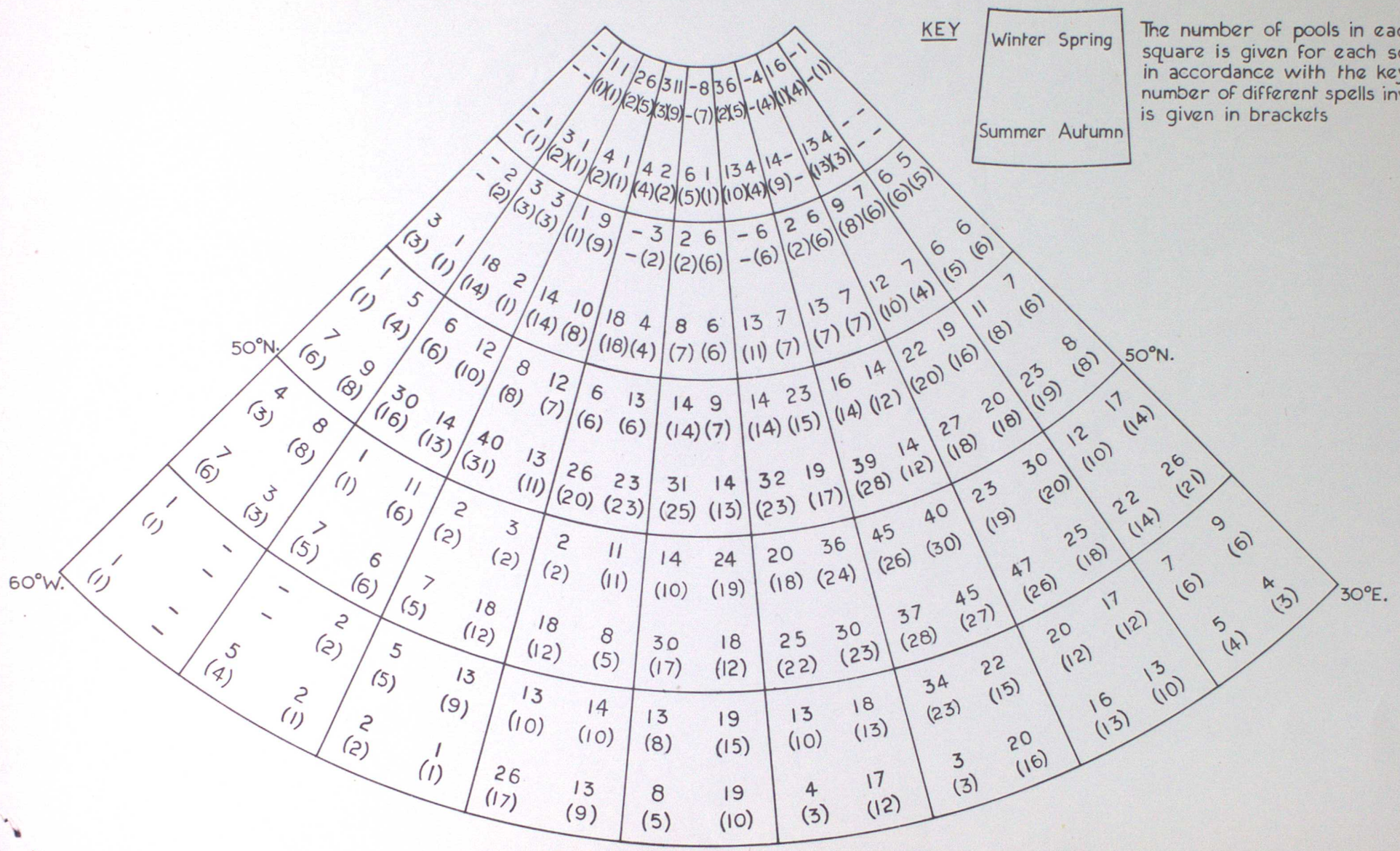


Fig. 18 Distribution of cold pools
October 1946–September 1951